High pressure single-crystal elasticity of a mixed-composition garnet

Paul Ginsberg* and Jay D Bass

University of Illinois at Urbana-Champaign
* presenter

Garnet is a major component of the earth's upper mantle, transition zone, and uppermost lower mantle, potentially exceeded only by olivine and its high-pressure polymorphs over these regions. In order to properly determine the chemical composition and mineralogy of the upper mantle, we must have a detailed understanding of the effect of pressure, temperature, and composition on the elasticity of garnet. Garnet in the mantle is represented by a solid solution of Mg, Fe, and Ca, forming pyrope (py), almandine (alm), and grossular (grs), with Si gradually substituting for Al at high pressure. The effects of these compositional variables on the elasticity of garnet is often considered to be linear. Here we present sound velocity measurements via Brillouin spectroscopy on a natural, eclogitic mixed garnet of composition $Py_{81}Grs_{11}Alm_{8}$. Single-crystal elastic moduli were determined, up to 14 GPa. Values for the elastic moduli at ambient conditions are (in units of GPa): K_0 = 160.6(3), G_0 = 89.4(1), C_{11} = 278.7(10), C_{12} = 101.6(11), and C_{44} = 90.0(3), with aggregate sound velocities Vp =8.90(4) km/s and Vs = 5.03(3) km/s and ρ_0 = 3.534(6) g/cm^3. The percent difference between our ambient values and those of a modal mixture of the garnet endmembers is: ΔK = -8.2(2)%, ΔG = -3.8(1)%, ΔC_{11} = -7.6(4)%, ΔC_{12} = -7(1)%, ΔC_{44} = -3.8(3)%, ΔVp = -2.0(4)%, and ΔVs = -0.8(6)%. Aggregate sound velocities were fit to a third order finite-strain EOS to determine dK/dP and dG/dP, as well as the density at high pressure. Our resulting best-fit parameters for the aggregate elastic properties are: dK/dP = 4.08(3), dG/dP = 1.20(2). Compared to pyrope, our pressure derivatives are similar for the bulk and shear moduli, but different for the single-crystal moduli. At ambient conditions, garnets are widely observed to be acoustically isotropic or nearly so. However, we find that the magnitude of the anisotropy factor increases with pressure, from A = 0.010 at ambient pressure, to A = -0.035 at 14 GPa. Most single-crystal sound velocity measurements on mixed composition garnets have shown little deviation from a linear mixing model. However, a recent static compression study on two eclogitic mixed-composition garnets reports a similarly low K_0 as observed from our results. Understanding the contribution of complex garnets to the elasticity of the mantle may require a larger range of compositions to be measured under real mantle P,T conditions.